Brass Tacks

An in-depth look at a radio-related topic

Managing common-mode current

Have you ever heard these complaints?

- *My electric range buzzes when I'm transmitting.*
- *Every time I transmit, my Wi-Fi router stops working.*
- *When I transmit, my kitchen GFCI breaker pops.*
- *My lights turn on as soon as I transmit on 10 meters.*
- *Every time I key up in the car, my dash touchscreen blanks out.*
- *When I start talking on 80 meters, the pump to our air bed starts up.*
- *My wired cameras shut down when I transmit, but the wireless ones remain unaffected.*
- *As soon as I start transmitting, my electric recliner starts moving.*
- *When I tie my coax to the metal mast, the SWR jumps way up.*
- *Occasionally, when I start speaking into the mic, my smoke alarm goes off.*

And then, have you heard these corresponding 'remedies'?

- *As soon as I moved my Wi-Fi router a few feet away, the problem stopped.*
- *When I reduced my transmit power, my TV no longer blanked out.*
- *As soon as I grounded my antenna, my keyboard problems went away.*
- *When I re-routed the coax, my motion-activated lights stopped acting up.*
- *I got a different brand of security camera, and the problem went away.*

What these people are reporting is known as RFI, or radio frequency interference. It's not interference that they're hearing on the radio, but observing on some other equipment. Many, if not all of these complaints could be the result of *common-mode current*, or CMC, also called *shack RF* and *RF feedback*. On the surface, this troublesome phenomenon seems quite undesirable, but as will be shown, CMC can be not only desirable, but necessary for the proper function of radio.

Many of these are reported so frequently, and the mention of CMC is mentioned so rarely, that it tells me most hams are simply unaware of the connection between the two. While CMC might not be responsible for *all* the abovementioned effects, experience tells me that the relationship is way underestimated, misunderstood, or unknown, and hence the reason for this discussion. Let's look first into exactly what CMC is, then distinguish between the wanted and unwanted occurrences, and finally how to manage the undesirable ones.

What common-mode current is

If we apply a DC (direct current) voltage on a wire of a circuit, the flow establishes both an electric field and a magnetic field, but they have little effect on other nearby conductors because the fields are constant, which keeps them from coupling. Applying an AC (alternating current) voltage will result in the periodic reversal of current direction, which results in a periodic change of direction and strength in the electric and magnetic fields as well (Faraday's Law). This periodic change in the electric and magnetic fields (known collectively as *electromagnetic radiation*, or radio waves) propagates outward in all directions, coupling with nearby conductors and inducing a voltage in them (Induction).

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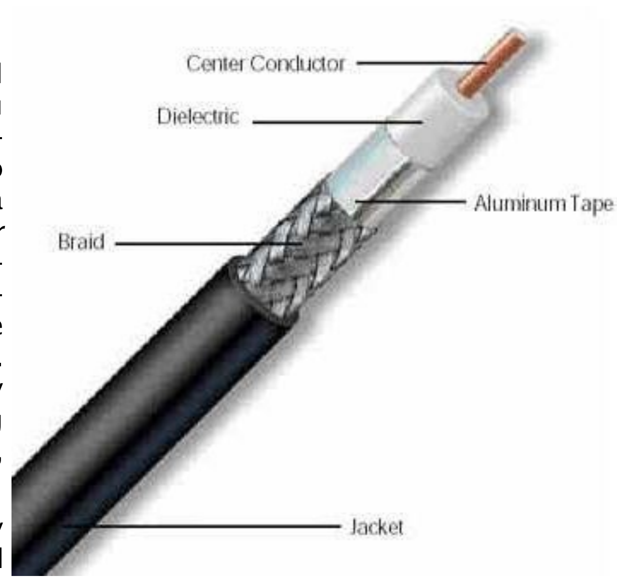
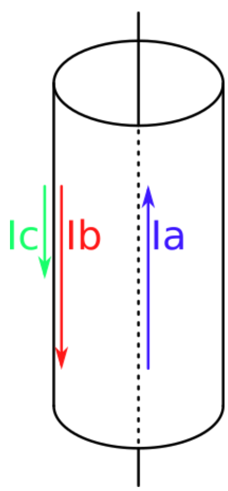
Herein lies the problem, because those nearby conductors could be in your Wi-Fi router, your recliner, your security cameras, and your display screen. Fortunately, the two wires in most AC pairs are typically close enough together that their equal and opposite fields actually cancel each other out, leaving little to radiate onto our appliances. This AC “wire” pair could be the two conductors of coax (coaxial cable), for example, which function the same way, the radiation from each conductor completely canceling that of the other conductor.

Role of coax in CMC



Coax is an interesting type of feed line, and understanding how it works can help you avoid some of the pitfalls related to CMC. Coaxial cable is so-called because it contains two cylindrically shaped conductors that share a common axis (co-axial), the *center conductor* and the outer *shield* or braid. The two conductors are separated from each other by an insulator called the *dielectric*, which surrounds the center conductor and is covered by the shield. This construction provides the coax with many advantages, including resistance to coupling with nearby metal objects and high durability, not to mention its sheer convenience.

Just like with any conductor, as the frequency of its AC signal increases, more of the signal is concentrated away from its center (because RF current is repelled by the densest magnetic field), a phenomenon known as the *skin effect*. Because of this effect, the "skin" acts as sort of an insulator, and the majority of the center conductor RF signal then travels in its outer-most depth. But due to its interaction with the center conductor, the majority of the shield half of the RF signal travels within the inner-most depth of the shield, called *proximity effect*. And because all of the RF signal is confined within the coax shield, the two resulting radio waves cancel completely through destructive interference and are not radiated. This behavior, in which the electrical RF signals flow in equal but opposite directions is referred to as *differential-mode current*, or DMC.



It's possible for an RF signal to travel within the outer-most depth of the shield (I_c), as well as within the inner-most depth (I_b). We refer to this action as *common-mode current*, the subject of our discussion. This extra path of current a) has no equal and opposing current to cancel its electromagnetic signal, and b) is not confined within any shielded barrier, so ***its resulting RF waves are broadcast outward, turning the coax into a long transmitting antenna***, radiating its signal all over surrounding equipment, such as the Wi-Fi router, the security cameras, and the recliner. Now that you know what it is and how it works, let's find out where it comes from.

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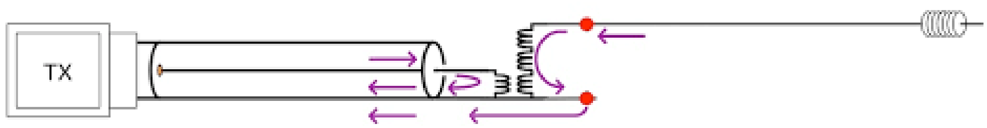
How unwanted CMC originates

Normally, balanced antennas such as dipoles, dipole types (doublet, G5RV, folded, fan, etc.), and Yagi beams are symmetrically constructed, such that the signal path lengths and material types of both sides of the antenna are reasonably identical. This way, what an electrical RF signal encounters on one side of the antenna, it will encounter on the other.

But, an unbalanced antenna, such as an OCFD (off-center-fed dipole), end-fed, or inverted-L will have a signal return path that has an unequally long or no conductive path to return on, and so will be forced to make up the missing length by using the coax shield. And because its signal is not (typically) flowing differentially with another confined signal, it's not subject to proximity effect. Again, this forces the signal to flow in the outer-most depth of the coax shield, resulting in waves that are radiated into the surrounding environment.



The farther the feed point is from the center of the antenna, the more unbalanced is the antenna, and therefore the more undesirable CMC is generated. Dipole antennas are the least problematic, OCFD (off-center-fed dipoles) are in between, and end-fed antennas tend to be the most problematic. A paradox here, however, is that without *some* degree of CMC, an end-fed antenna will not work at all, so a very high-impedance choke will be counterproductive on one.

Why you should care about CMC

The better you understand CMC, the less likely you'll become a victim to it, and the more quickly and effectively you'll be able to solve resulting RFI issues. In the first paragraph, I mentioned that the complaints were more about RFI observed through their appliances. But, because of reciprocity, CMC can work in the other direction, and cause your station to be affected by interference from appliances, and by the same mechanism, which is your unbalanced antenna system. Therefore, solving CMC issues that affect your appliances can also help reduce the effects of CMC on your receiver performance.

CMC can change your antenna propagation properties, acting as a kind of counterpoise, adding and subtracting from your signal. Because of this, many hams find themselves believing the myth that lowering SWR will reduce CMC and its effects on RFI, such as shack RF. Indeed, some find that when they reduce the SWR on a particular band, the RFI that affected a piece of home gear stopped plaguing it. What likely happened is that, by changing some antenna property to lower the SWR, they could have altered (fixed) the CMC that was generating the RFI to begin with.

The same goes for grounding. If grounding the antenna mast seems to remove the RFI symp-

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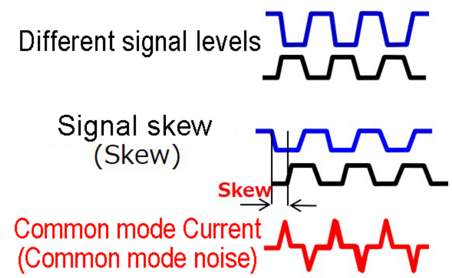
toms, chances are the problem (CMC) still exists, and grounding is simply masking the symptoms, which can easily show up elsewhere. Grounding is necessary for an outdoor antenna, and can actually remove some common-mode noise if done properly. But, it's not a substitute for an actual solution, which is to prevent CMC from running down your coax in the first place.

If the CMC is received by your coax from an external source, such as a nearby broadcast radio transmitter or a plasma display TV, chances are, the phase of their signals will not match that of the RF signal in your coax traveling in the same direction. As a result, voltage spikes will be generated, known as ***common-mode noise***, which is often difficult to distinguish, but adds to the ever-present level we already have to endure.

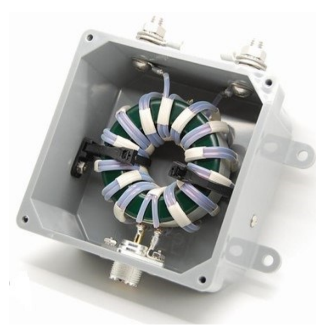


Managing CMC

There are typically three ways that radio waves from CMC can be a nuisance: they can be transmitted by your coax onto electronic household equipment, normal (external) radio waves can be received by your coax and brought into your transceiver as interference, or CMC can cause your coax to couple with nearby metallic objects, altering the characteristics of your antenna system, often resulting in false SWR readings. One of the most obvious effect tends to be your antenna radiating onto your own coax, electrically bringing the signal back into your home and re-radiating the signal all over things in your house.

To reduce the CMC traveling on your coax or being imposed onto your coax, you'll need to install a *common-mode choke* (also called a ***choke balun***, ***current balun***, and ***isolator***), a device that's designed to attenuate (reduce in strength) the CMC, dead in its tracks. By the same method, a common-mode choke can attenuate RF signals originating with external objects, such as those from a failing solar charge controller, an LED show, a wall charger, or a malfunctioning appliance, from being induced onto your coax shield.

To make one, wrap twelve turns of a three-foot section of RG-58 through an FT-240-31 ferrite toroid. That simple device will work for most HF and VHF applications. For a greater CMC attenuation, you can make a more rugged one, or purchase a reputable one. For VHF, often a simple coil made from six 6-inch-diameter turns installed right under your antenna is sufficient. Whichever you choose, it must be effective for creating large impedances against CMC while remaining low-impedance for DMC on your band(s) of choice. Locate the balun or isolator, along with the un-choked portion of the coax, *as far from the transceiver as practical.*



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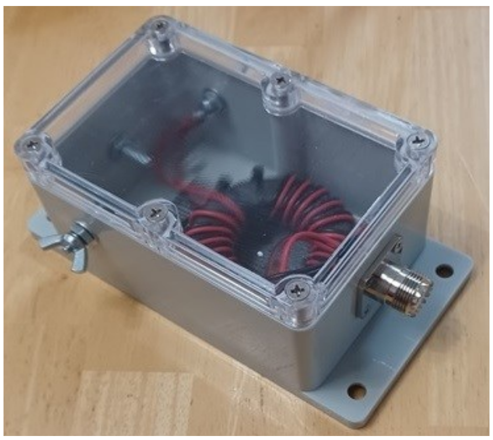
One way to reduce the RF signal from CMC coming through the power cables, speaker wires, and computer peripherals is to apply ferrite beads to them. Many wired keyboards, microphones, and USB cables are equipped with them from the factory. Remember that the entire conductor acts like a receiving antenna, so be sure to install them on both ends if possible. And if your ferrite bead hole is large enough, wrap multiple loops of your wire through it.



Some CMC is good

Each element of an antenna, whether that's a leg of a dipole, a driven element of a Yagi, or the radiator of a monopole, must conduct its RF signal without that signal being canceled by an equal and opposite one. And when it does conduct the AC of the RF signal, it converts the electrical signal into a radio wave, as described above. This means that all antennas work by CMC, and that without CMC they cannot perform their invisible magic.

What CMC is not turned into radio waves is returned to the transmitter over the coax shield. Antennas can't always be the perfect lengths, forcing us to accept *some* CMC as collateral damage. Furthermore, many of us enjoy the convenience of multi-band antennas, such as fan dipoles, end-feds, and random wires, but they typically contain more CMC travel path than that needed for the transmitted signal. Once again, in their cases, we can compensate for poor antenna design to some extent by an appropriate common-mode choke.

Summary

CMC, or common-mode current is not widely understood and in most cases an undesirable phenomenon that can cause your radio station to wreak havoc on appliances with sensitive or radio-frequency electronics. It can also make your receiver susceptible to extra noise by external equipment. CMC is a fact of life, not only because it's very difficult to completely eliminate, but also because it's necessary for normal radio transmission. But you can take steps to reduce the effects of CMC, if not the current itself.

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